A Survey on Neural Networks in Automated Negotiations

Ioannis Papaioannou
National Technical University of Athens, Greece

Ioanna Roussaki
National Technical University of Athens, Greece

Miltiades Anagnostou
National Technical University of Athens, Greece

INTRODUCTION

Automated negotiation is a very challenging research field that is gaining momentum in the e-business domain. There are three main categories of automated negotiations, classified according to the participating agent cardinality and the nature of their interaction (Jennings, Faratin, Lomuscio, Parsons, Sierra, & Wooldridge, 2001): the bilateral, where each agent negotiates with a single opponent, the multi-lateral which involves many providers and clients in an auction-like framework and the argumentation/persuasion-based models where the involving parties use more sophisticated arguments to establish an agreement. In all these automated negotiation domains, several research efforts have focused on predicting the behaviour of negotiating agents. This work can be classified in two main categories. The first is based on techniques that require strong a-priori knowledge concerning the behaviour of the opponent agent in previous negotiation threads. The second uses mechanisms that perform well in single-instance negotiations, where no historical data about the past negotiating behaviour of the opponent agent is available. One quite popular tool that can support the latter case is Neural Networks (NNs) (Haykin, 1999).

NNs are often used in various real world applications where the estimation or modelling of a function or system is required. In the automated negotiations domain, their usage aims mainly to enhance the performance of negotiating agents in predicting their opponents' behaviour and thus, achieve better overall results on their behalf. This paper provides a survey of the most popular automated negotiation approaches that are using NNs to estimate elements of the opponent's behaviour.

The rest of this paper is structure as follows. The second section elaborates on the state of the art bilateral negotiation frameworks that are based on NNs. The third section briefly presents the multilateral negotiation solutions that exploit NNs. Finally, in the last section a brief discussion on the survey is provided.

NEURAL NETWORKS IN BILATERAL NEGOTIATIONS

In (Zhang, Ye, Makedon, & Ford, 2004) a hybrid bilateral negotiation strategy mechanism is described that supplies negotiation agents with more flexibility and robustness in an automated negotiation system. The framework supports a dynamically assignment of an appropriate negotiation strategy to an agent according to the current environment, along with a mechanism to create new negotiation rules by learning from past negotiations. These learning capabilities are based on feedforward back-propagation neural networks and multidimensional inter-transaction association rules. However, the framework is not adequately described and defined and the neural networks are not specifically instantiated. Additionally, there are neither quantitative nor qualitative experimental results for real world cases. Finally, the format of the input to the generic network that is presented is ambiguously described.

In (Zeng, Meng, & Zeng, 2005), the authors employ a neural network to assist the negotiation over very specific issues from a real world example. The network is trained online by the past offers made by the op-

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ponent, while both the buyer and the seller agent have the ability to employ the proposed network. However, the experimental data sets are very restrictive and do not address the diversity of those that can be arisen in real scenarios. Additionally, the authors do not present the actual size of the hidden layer, a parameter that is extremely crucial with regards to the appropriateness to use such a network in a real time negotiation procedure by an agent with limited resources.

Furthermore, in (Rau, Tsai, Chen, & Shiang, 2006), the authors studied the negotiation process between a shipper and a forwarded using a learning-based approach, which employed a feedforward back-propagation neural network with two input data models and the negotiation decision functions. Issues of the negotiation were the shipping price, delay penalty, due date, and shipping quantity. The proposed mechanism was applicable to both parties at the same time and the network architecture was chosen based on past similar attempts, following a very restrictive pattern for the number of the hidden layer's neurons. The conducted experiments showed an overall improvement of the results for both negotiating parties, while the framework was proven stable and with small deadlock probability. However, as its authors support, further experimentation is required especially with regards to a wider variety of strategies and possibly more suitable network architectures for the hidden layer.

In (Carbonneau, Kersten, & Vahidov, 2006), a neural network based model is presented for predicting the opponent's offers during the negotiation process. The framework was tested over a specific set of experimental data collected from other existent frameworks and it is highly adjusted to these data. The purpose of this solution is not only to predict the opponent's next offer, but also the perception for the specific procedure, i.e. an overall vision on why everything is happening and where the procedure is led. Thus, the prediction of the opponent's next round offer is only a part of the network's output. However, the chosen experiment set is constrained and doesn't examine the effectiveness of the framework on diverse strategies as those proposed in the very first steps of the area and are now mainly used (Faratin, Sierra, & Jennings, 1998). Additionally, although the authors support the view that their framework is proper for real-time environments, the fact is that the resulted network is difficult to be online trained, mainly because of its size and the resources that are required for such training. Thus, this network architecture is probably inappropriate for mobile agents' environments, and something smaller and more specific should be designed, due to the limitations that these environments share.

Moreover, in (Oprea, 2003), the author presents a shopping agent, which is capable of negotiating in online bilateral, multi-issue procedures using an offline created and trained feedforward neural network in order to increase its profitability by adapting its behaviour according to its opponent's. The purpose of the neural network's application on each procedure is to predict the opponent's next offer on a round by round basis and thus, model its behaviour and intentions in order to finally achieve a better or even the best possible deal. With the exploitation of the neural network the shopping agent can decide during the online phase of negotiation, which is the opponent's strategy and estimate its reservation value. Concerning the experiments conducted, the author uses the well-justified negotiation tactics presented in (Faratin, Sierra, & Jennings, 1998) in order to test the proposed solution and concludes that the framework is working well in case of medium or long term agents' deadlines. However, the results presented are not thoroughly justified and more extreme opponent strategies should be tested in order to decide on the network's adequacy for such environments. Probably, the three hidden layer neurons might not be sufficient for such cases and long-term estimations.

Finally, Papaioannou et al. have recently designed and evaluated several single-issue bilateral negotiation approaches, where the Client agent is enhanced with Neural Networks. More specifically, in (Roussaki, Papaioannou, & Anagnostou, 2006), the Client agent uses a lightweight feedforward back-propagation NN coupled with a fair relative tit-for-tat imitative tactic, and attempts to estimate the Provider's price offer upon the expiration of the Client's deadline. This approach increases the number of agreements reached by one third in average. In (Papaioannou, Roussaki, & Anagnostou, 2006), the performance of MLP and RBF NNs towards the prediction of the Provider's offers at the last round has been compared. The experiments indicate that the number of agreements is increased by ~38% in average via both the MLP- and the RBF-assisted strategies. Nevertheless, the overall time and the number of neurons required by the MLP are considerably higher than these required by the RBF. In (Roussaki, Papaioannou, & Anagnostou, 2007), MLP and GR NNs have been used by the Client agent in order to identify the unsuccess-

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